Biology of the Tropical Catfish (Family: Clariidae) with Special Emphasis on its Suitability for Culture (Including a Bibliography of the Clariidae and Related Topics)

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Fisheries and Marine Service
Manuscript Report 1458

December 1977

BIOLOGY OF THE TROPICAL CATFISH (FAMILY: CLARIIDAE) WITH SPECIAL EMPHASIS ON ITS SUITABILITY FOR CULTURE (INCLUDING A BIBLIOGRAPHY OF THE CLARIIDAE AND RELATED TOPICS)

by

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PREFACE

This review and the work entailed in compiling this report were carried out while the author was employed by the Department of Agriculture, University of Rhodesia. At this time it was decided to prepare a detailed "Species Synopsis" on the family Clariidae. The present manuscript is a preliminary coverage of the topic and the aim of producing this interim publication is to obtain suggestions and criticism of all interested parties involved in work on the Clariidae.

The author would appreciate any suggestions, additions, or alterations that can be forwarded by workers in this field before July 1978.

ABSTRACT

Clay, D. 1977. Biology of the tropical catfish (Family: Clariidae) with special emphasis on its suitability for culture (including a bibliography of the Clariidae and related topics). Fish. Mar. Serv. MS Rep. 1458. 68 p.

All available literature relevant to the culture of the Clariidae have been reviewed and evaluated. The present production of the catfish in inland African fisheries is estimated at over 20% by weight of the commercial catch. *Clarias* spp. is a particularly suitable fish for culture because of its dual respiratory system, its extreme hardiness, its broad feeding habits, and its very wide range of habitat. Emphasis is placed on reviewing the reproduction and digestion of these fish and their importance for culture. A need of local variety trials is shown to be necessary in order to investigate the potential for culture of the indigenous fishes of Africa and Asia.

Key words: Clariidae, culture, bibliography, growth, commercial fishing, reproduction, feeding, habitat, respiration, anatomy

RÉSUMÉ

Clay, D. 1977. Biology of the tropical catfish (Family: Clariidae) with special emphasis on its suitability for culture (including a bibliography of the Clariidae and related topics). Fish. Mar. Serv. MS Rep. 1458, 68 p.

Toute la documentation accessible sur l'élevage des Clariidae a été passée en revue et évaluée. On estime que la pêche actuelle de poissons-chats dans l'intérieur du continent africain représente plus de 20%, en poids, de la pêche commerciale. L'espèce *Clarias* convient particulièrement à l'élevage à cause de son système respiratoire double, de sa vigueur incomparable, de la diversité de ses habitudes alimentaires et de sa très grande faculté d'adaptation. L'accent est mis sur l'étude de leur système respiratoire et digestif, et sur leur importance piscicole. Il apparaît nécessaire de procéder à une sélection des variétés locales pour être en mesure d'évaluer les possibilités d'élevage des poissons indigènes d'Afrique et d'Asie.

INTRODUCTION

The tropical catfish is an air breathing, non-scaled, omnivorous, potamdromous member of the family Clariidae. The Indian catfish (*Clarias batrachus* Linnaeus), is found throughout the Indian sub-continent, the Far East, and has recently been introduced into both Hawaii and continental U.S.A. The Asian catfish (*Clarias macrocephalus* Gunther) is located in the Far East. The major commercial members of the African catfish, the subject of this review, are *Clarias gariepinus* Burchell, *Clarias lazera* Cuvier and Valenciennes, and *Clarias mossambicus* Peters. They are thought by some, including the author, to be geographical variations of the same species. Jubb (1967) has synonymized *C. gariepinus* and *C. mossambicus*.[1] These three species are distributed throughout Africa from the Orange River in the south to the Nile delta in the north (Fig. 1).

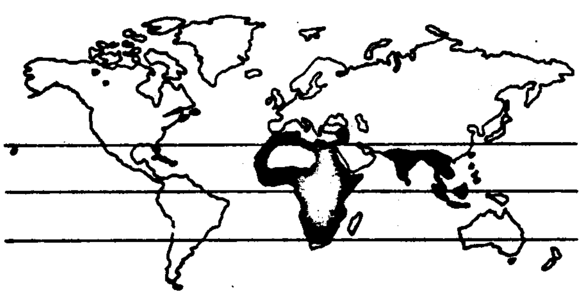

Fig. 1. World distribution of the family Clariidae (after Hora 1937; Menon 1951; Ogilvie and Goodrick 1968).

Although many authors have worked in the field of Clariidae taxonomy (Barnard 1943; Boulenger 1886, 1896, 1899, 1902, 1903, 1911; Deraniyagala 1958; Greenwood 1958, 1961; Gunther 1867; Jackson 1955, 1959; Jubb, 1964; Leriche 1901; Mann 1971; Poll 1942, 1943; Vaillant 1897) a detailed synthesis is now needed in light of present knowledge. Table 1 gives a brief résumé on the commercially important Clariidae with their respective scientific and common local names.

C. gariepinus can make up over 50% by weight of the commercial catch in some Central African fisheries (Harding 1960). More frequently, as in Lake Kariba, they make up less than 20% by weight of the catch (Anon. 1972, 1973, 1974; Harding 1964); even with this lower figure they must be considered one of the most important fish of African waters. Mwanza (1972) found *Clarias* sp. to be the only one of the three important commercial species to be unaffected by the 1968 drying out of Lake Chilwa in Malawi.

The tropical catfish has for many years suffered an unjust stigma in Africa as a trash fish, and recently as a nuisance fish in the U.S.A. (Idyll 1969). Jubb (1953) stated that all fish in farm dams were useful except the 'barbel' and furthermore that it was the only common fish that did not require a fish ladder to help populate new dams. More recent inquiry regarding this fish has sparked interest in its potential for aquaculture. Many authors (Brown 1955; Coureur and Spaas 1956; Van der Waal 1970) as well as the United Nations Development Program (UNDP) (Micha, pers. comm.) have begun investigations into various aspects of the biology of the tropical catfish, specifically for culture. Farming the Asian catfish in Thailand has developed over the last 15 yr into a large and growing industry (Sidthimunka 1972). The tropical catfish is very important in Africa and the Far East in both commercial catches and consumer preference. One consideration, important to the African situation, is that many tribes will not willingly eat the catfish because of taboos related to its scaleless body. Such feelings are also found amongst the Jewish population of Israel.

One of the earliest and most interesting accounts of *Clarias* sp. was written by the Rev. Boake in 1866. He reported that in the Mootoo Rajawelle swamp of [Sri Lanka] the vegetation was a "continuous sod ... firm enough to support the weight of natives ... cutting (the) long grass ... while on some of the firmer parts bullocks were to be seen grazing." Under this thick mat was 60 cm of water kept very muddy with "the consistency of thick pea soup" by the "large numbers of Hoongas *(Heteropneustes fossilis)* and Magooras *(Clarias teysmanni* Bleeker)." The local people of Ceylon used the knowledge that the tropical catfish were air breathers in order to catch them (Boake 1866). The fishermen cut several holes about 1 m diameter in the "sod" (described above). This was done at night when the fish were more active, and the frequent breathing at the surface indicated their presence. The next day the sod and peat in a large diameter ring around the hole were trampled into the swamp bottom, thus forming an enclosed ring of very muddy water with the fish trapped inside. The hole was then covered with long grass criss-crossed in such a way as to form a mesh-like net. When the fish began rising to breathe, it gave an advance warning by the air bubbles released before surfacing. The fishermen thus forwarned had little difficulty in catching the fish as it forced its head up

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[1]Throughout this paper wherever *Clarias mossambicus* is discussed it will be referred to as *Clarias gariepinus*.

Table 1. A list of the major species of the Clariidae of commercial importance and their common names.

Scientific name	Synonym	Common name/location	Language
Clarias macrocephalus (Gunther)		Pla Duk Oui/Thailand	Thai
		Pla Duk/Thailand	Thai
Clarias batrachus (Linnaeus)	*C. magur*	Freshwater catfish/India	English
		Teysmann's spotted catfish/India	English
		Magur, Kagga, Ana meenu, Marpoo/India	?
		Magura/Sri Lanka	?
		Pla Duk Dan/Thailand	Thai
		Pla Duk/Thailand	Thai
		Ca tre, Trey andeng/Cambodia	?
		Ca tre trang/Vietnam	Vietnamese
		Alabbiyog, Kawatsi/Philippines	?
		Keli, Ikan keli/Malaysia	Malayan
		Leleh, Ikan kalang, Pintet, Tjepi/Indonesia	Indonesian
		Nga rheo/Kymer Republic	?
		Walking catfish/U.S.A.	English
Clarias teysmanni (Blecker)		Magoora/Sri Lanka	?
Clarias lazera (Cuvier)		Nigerian mudfish/Nigeria	English
		Kullune, Kulumni, Arungu, Tarwada/Nigeria	Hausa
		Mali/Uganda	?
		Nyai/Uganda	?
		Garmout/Sudan	?
		Harmut/Egypt	Arabic
		Armut/Israel	Arabic
Clarias senegalensis (Cuvier & Valenciennes)		Catfish/Ghana	English
Clarias ngamensis (Castelnau)		Ndombi/Zambia, Rhodesia	?
		Blunt-toothed barbel/Zambia	English
		Blunt-toothed catfish[a]/Zambia	English
Clarias theodorae (Weber)		Brown barbel, Snake barbel/Zambia	English
		Mulonfi/Zambia	?
		Mulonge/Zambia	?
		Minga/Zambia, Rhodesia	?
Clarias gariepinus (Burchell)	*C. mossambicus* (Peters)	Barber/Republic of South Africa	Afrikaans
		Barbel/R.S.A., Rhodesia	English
		African catfish/Rhodesia	English
		Mpongo, Mulonge, Muta/Zambia, Tanzania	?
		Sharp-toothed barbel/Rhodesia, Zambia	English
		Sharp-toothed catfish[a]/Rhodesia, Zambia	English
		Maramba/Rhodesia	Shona
		Ndombi/Zambia, Rhodesia	?
		Mubando/Zambia, Rhodesia	?
		Black barbel, Zambezi barbel/Zambia	English
		Mlamba/Malawi	?
		Mali (Twang)/Uganda	?
		Nyaki (Kasonzi)/Uganda	?
		Mandev/Mozambique	Shangan
		Slamue chilu/Mozambique, Rhodesia	?
		Gariep/R.S.A., Botswana	Hottentot

[a]Name now accepted as 'official' common name (Smith 1975).

through the woven grass net. This method resulted in about 11 fish per hour being caught.

The hardy nature of these fish, exploited by the people of [Sri Lanka] for so many years, is still a source of frequent reports. Tait (1967) found that in a mass fish kill in the Kafue River system of Zambia no catfish died, although *Tilapia* spp., *Hepsateus* sp., *Synodontis* sp., and *Schilbe* sp. all died of unknown causes.

COMMERCIAL IMPORTANCE OF THE CLARIIDAE

The Clariidae of Africa is one of the most important commercial families of freshwater fishes in traditional subsistence and modern commercial fisheries[2] (Tables 2 and 3). Many methods are used in fishing but the majority of catfish are landed by the many gillnet fisheries of African inland waters. Although Bowmaker (1973) found *C. gariepinus* not effectively caught in gillnets in a riverine estuary of Lake Kariba, Ratcliff (1972) found gillnets to be the major means of catching the catfish in Lake Malawi. There would appear to be great variation in the catchability of *Clarias* spp. in gillnets in various locations. Other methods seem to have less variability; seine nets appear to be universally ineffective in catching catfish; this may be due to the diving behaviour of the Clariidae. When cornered or disturbed, these fish dive into the mud allowing the toe rope of the seine to slide upward over their bodies. Williams (1960) gives records for the same river for a gillnet fishery and a seine-net fishery, the latter catches ½ to ¼ by weight of the former (Table 2).

Longlines are widely used in Tanzania (Bailey 1966; Soulsby 1960) and other African countries; in some lakes they are nearly 100% selective for *Clarias* spp. (Clay 1972, Mortimer 1959) because few other indigenous fish take still bait. Such knowledge would be a useful management tool to allow more complete cropping of this very productive fish. In small dams (as in Table 3) where the Clariidae can make up over 30% of the production, this very selective form of fishing requiring a low capital investment would allow an economic harvest of at least one-third of the total production. This would be especially important where gillnets could not offer a large enough economic return. During the annual spawning migrations in the Barotse flood plains of Zambia, traditional spear fishing is very widely used to harvest *Clarias* spp. (Bell-Cross 1974). Many of the very colourful traditional fishing methods such as basket fishing, trap fishing, and weir fishing are all effective in catching *Clarias* spp. although not totally selective for them.

[2]The purse-seine fishing of Lake Tanzania and Lake Kariba are notable exceptions to this.

As well as being an important fish in tonnage landed, it is one of the most sought after fish in Africa. Balon (1972) lists *C. gariepinus* in the top four highly preferred fish of Lake Kariba, while Mann (1964) found *Clarias* sp. liked by the African consumers for taste and high fat content. Often the likes or more particularly the dislikes are regional in nature and related to taboos dealing with scaleless fish.

The nutritive value of *C. gariepinus* has been investigated by Watanabe (1971). Water was found to be approximately 81% of the live weight, rising in winter with a corresponding drop in oil level which is generally about 2%. Protein levels are about 16% with ash levels running at 1%. Watanabe placed the loss after commercial gutting and removing the head at 44%, and after filleting at 66%.

Figure 2 gives some indication of the seasonal nature of catfish catches in gillnets.

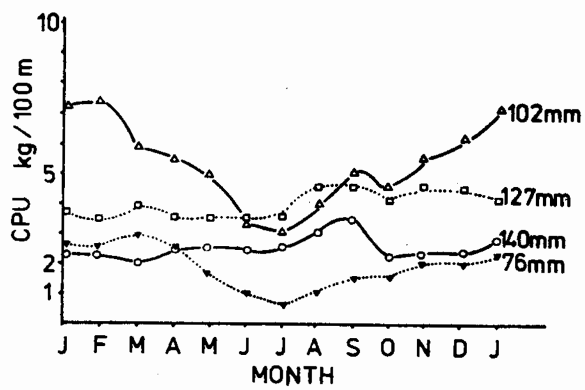

Fig. 2. Seasonal variation in the catch per unit effort of *Clarias gariepinus* of the commercial gillnet fishery of Lake McIlwaine (data averaged over a 13-yr period). The numbers at the end of each of the four curves are gillnet stretched-mesh measurements.

Although the "seasons" do not necessarily coincide in all lakes, a cyclical pattern is evident in most. In the Mwenda estuary of Lake Kariba the catch per unit effort (CPU) of *Clarias* sp. ranged throughout the year from 0.3-1.6 kg 100 m^{-1} per night set (Bowmaker 1973). Great variation also occurs in catfish catches from different lakes. In contrast to the low yield of the Mwenda estuary of Lake Kariba, Lake Mweru, Zambia, has yielded approximately 6.3 kg 100 m^{-1} per night set (Bowmaker 1963), while the CPU in Lake McIlwaine, Rhodesia, has ranged from 2.5 to

Table 2. Importance of the family Clariidae in Africa as percent of the catches of commercially valuable fishes (species of Clariidae as per species code and fishing method as per method code).

Location	Fishing method	Percent catch by weight	Percent catch by numbers	Author
Lake Tanzania, Tanzania	L.F.	75 (C.spp.)		Soulsby (1960)
Malya Dam, Tanzania	C.G.N.F.	3 (C.g.)		Bailey (1966)
Lake Kitangiri, Tanzania	L.F. & S.F.	major[d] (C.g.)		Lockley (1960)
Lake Ruka, Tanzania	C.G.N.F. (B)	10-50 (C.spp.)		Mann (1964)
Barotse[a], Zambia	C.G.N.F.	4.5 (C.g.)		Bell-Cross (1974)
	C.G.N.F.	4.5 (C.n.)		
	W.F.	6.8 (C.n.)		
	T.F.	major[d] (C.g.)		
	E.G.N.F.	7 (C.g.)	2 (C.g.)	Duerre (1969)
	E.G.N.F.	8.5 (C.n.)	4 (C.n.)	
	C.G.N.F.	4.5 (C.g.)	4.3 (C.g.)	
	C.G.N.F.	2.2 (C.n.)	2.2 (C.n.)	
Kafue[a], Zambia	C.G.N.F.	major[d] (C.g.)		Carey (1971)
	C.G.N.F.	major[d] (C.n.)		
	C.G.N.F.	43 (C.spp.)		MacLaren (1956)
	S.N.F.	6 (C.spp.)		
Kafue River, Zambia	C.G.N.F. (1954-1958)	29-52 (C.spp.)		Williams (1960)
	S.N.F. (1954-1958)	7-24 (C.spp.)		
	S.N.F.	31 (C.spp.)	14 (C.spp.)	Everett (1971)
Lake Bangweulu, Zambia	C.G.N.F.	60 (C.g.)		Harding (1960)
	C.G.N.F.	7 (C.m.)		
Lake Mweru-Wantipa, Zambia	L.F.		90 (C.g.)	Allen (1964)
	C.G.N.F.		7 (C.g.)	
	C.G.N.F.		<1 (C.g.)	Allen (1965)
Lundazi Dam, Zambia	E.G.N.F. (1954)	42 (C.g.)	25 (C.g.)	Mortimer (1959)
	E.G.N.F. (1955)	50 (C.g.)	28 (C.g.)	
	E.G.N.F. (1956)	50 (C.g.)	27 (C.g.)	
	E.G.N.F. (1957)	44 (C.g.)	23 (C.g.)	
	E.G.N.F. (1958)	20 (C.g.)	8 (C.g.)	
Lungwewungu River, Zambia	C.G.N.F.	14 (C.g.)		Bell-Cross (1974)
North Kashiji River, Zambia	C.G.N.F.	30 (C.g.)		
South Kashiji River, Zambia	C.G.N.F.	4.6 (C.g.)		
Small stream, Zambia	A.		14 (C.spp.)	Mortimer (1965)
Stream, Zambia	W.F.	7 (C.spp.)		Bell-Cross (1971)
Zambezi River, Zambia	C.G.N.F.(Below dam wall)	6 (C.g.)		Bowmaker (1960)
Zambezi River, Rhodesia	C.G.N.F.(before closure of Kariba Dam wall)	3-5 (C.g.)		Harding (1964)
Lake Kariba, Rhodesia	C.G.N.F.	20 (C.g.)		Harding (1964)
	C.G.N.F.	18 (C.g.)		Coke (1968)
	C.G.N.F.	16 (C.g.)		Van der Lingen (1971)
	E.G.N.F.		5 (C.g.)	Allen (1965)
	C.G.N.F. (1971)	4.5 (C.g.)		Anon. (1972)

Table 2. (cont'd)

Location	Fishing method	Percent catch by weight	Percent catch by numbers	Author
	C.G.N.F. (1972)	3.3 (C.g.)		Anon. (1973)
	C.G.N.F. (1973)	3.8 (C.g.)		Anon. (1974)
	P.	2 (C.g.)		Balon (1973)
(Mwenda Estuary, Lake Kariba)	E.G.N.F.	6.3 (C.g.)	5 (C.g.)	Bowmaker (1973)
Mwenda River, Rhodesia	P.	28 (C.g.)		
Lake McIlwaine, Rhodesia	C.G.N.F.	20-76 (C.g.)		Unpublished[b]
	E.G.N.F.		10 (C.g.)	Van der Lingen (1962)
Lake Kyle, Rhodesia	E.G.N.F.	5.3 (C.g.)	1.6 (C.g.)	Minshull (1975)
	S.N.F.	1.9 (C.g.)	0.08 (C.g.)	
	A.	2.5 (C.g.)	0.9 (C.g.)	
Lake Chilwa[c], Malawi	C.G.N.F. & P.S.F. (1965)	25 (C.spp.)		Ratcliff (1972)
	C.G.N.F. & P.S.F. (1966)	40 (C.spp.)		
Zambezi River, Mozambique	C.G.N.F. (before closure of Cabora Basa Dam)	17 (C.g.)	3.5 (C.g.)	Morais (1974)

Footnotes

[a]Flood plain; [b]Unpublished data from Tiger Bay Fisheries (Pvt) Ltd., Norton, Rhodesia (13-yr range) average over 50%; [c]Lake on a drying phase; [d]No figure given.

Species Code

C.g. - *Clarias gariepinus*
C.n. - *Clarias ngamensis*
C.m. - *Clarias mellandi*
C.spp. - *Clarias* spp.

Fishing Method Codes

C.G.N.F. - Commercial gillnet fishery
E.G.N.F. - Experimental gillnet fishery
(B) - Bottom set
L.F. - Longline fishery
T.F. - Trap fishery
S.F. - Spear fishery
W.F. - Weir fishery
S.N.F. - Seine net fishery
P.S.F. - Purse seine fishery
P. - Poisoning
A. - Angling

Table 3. Importance of *Clarias gariepinus* in small dams of Rhodesia. (Data taken from publications and internal reports of Department of National Parks and Wildlife Management, Rhodesia.)

Location	Fishing method/date	% catch by Weight	% catch by Numbers	Author
Cleveland Dam, Salisbury	Experimental gillnet fishing			
	/May 1962	24.1	7.8	Toots (1968)
	/November 1962	6.2	1.7	
	/September 1967	27.7	14.5	
	/January 1968	24.0	7.9	
	Angling/1962-1966	8.4	4.0	
Silalabuhwa Dam, Insiza, TTL	Experimental gillnet fishing			
	/June 1970	3.3	2.0	Toots (1970)
	/March 1971	3.5	0.9	Toots (1971)
Nyambuia Dam, Marandellas	Experimental gillnet & seine net fishing/April 1969	90.0	66.0	Toots (1969a)
Nyakambira Dam, Marandellas	Experimental gillnet & seine net fishing/April 1969	0.0	0.0	Toots (1969a)
Gwenoro Dam, Gwelo	Experimental gillnet fishing /May 1974	58.0	10.0	Toots (1974a)
Ngamo Dam, Gwelo	Experimental gillnet fishing /April 1974	29.1	15.3	Toots (1974c)
Impali Dam, Selukwe	Experimental gillnet fishing /May 1974	61.0	40.0	Toots (1974a)
Whitewaters Dam, Lalapanzi	Experimental gillnet fishing /April 1974	27.4	10.2	Toots (1974c)
Ngondoma Dam, Ngondoma	Experimental gillnet fishing			
	/April 1969	78.0	34.0	Toots (1969b)
	/April 1971	7.9	1.4	
	/April 1974	19.1	6.3	
Pindi Park Dam, Banket	Experimental gillnet fishing /September 1974	35.0	9.0	Toots (1974b)
Chimwemwe Dam, Banket	Experimental gillnet fishing /1972	23.3	6.1	Toots (1972)
Ngesi Dam, Ngesi National Park	Experimental gillnet fishing			
	/March 1962	9.0	3.0	Van der Lingen (1962b)
	/June 1962	8.0	4.5	
	/October 1962	14.5	5.8	
Sebakwe Dam, Sebakwe National Park	Experimental gillnet fishing /June 1962	6.0	4.8	Van der Lingen (1962c)

7.8 kg 100 m^{-1} 24 h^{-1} over a 13-yr period (unpublished data from Tiger Bay Fisheries (Pvt) Ltd., Norton, Rhodesia).

The selectivity of some fishing methods should be utilized as a management technique to permit "catfish fisheries" on the major lakes of southern and central Africa. This would allow a heavy fishing pressure to be placed on this fish while not placing as much pressure on the less plentiful species. Many new dams will be built, hopefully with fish ladders incorporated into them, and it would be valuable to place commercial fisheries on these fish ladders during the floods to remove a percentage of all migrating fish. In the special case of *Clarias* spp. which are the only fish to move up the ladder at night (Bell-Cross 1960), special automatic traps harvesting all fish could be used during the hours of darkness.

From routine observations of commercial fisheries in Zambia, Bell-Cross (1974) found the numbers of large catfish to be increasing. This has been attributed to the reduction in numbers of the crocodiles once so plentiful on large African rivers. Although these larger catfish are of interest to individual sports fishermen, they are unlikely to increase the production of these fish which already produce an estimated one-fifth (20.1%) of the fish protein of East and Central Africa.

ANATOMY

Early writers (Angelopulo 1947) felt that the maximum size of the African catfish was dependent upon the locality in which it was caught. Although the size of the habitat can affect the maximum length, a more important factor appears to be the temperature regime of the environment. Personal observations by the author and data from several sources recorded by Bruton (1976) indicate that in Rhodesia and South Africa there is a definite trend to larger fish in more southern regions. The largest fish are found in the Orange and Vaal Rivers and the smallest "maximum" sized fish are found in Lake Kariba and the Zambezi River.

The head of *Clarias* spp. is a massive, broad, dorso-ventrally flattened structure, heavily armoured by very thick skull bones. It is covered by a very thin layer of skin through which can be seen the many small glanular tubercles (Fig. 3). The trunk stretches from the back edge of the skull to the uro-genital pores and is cylindrical. The caudal region makes up the rest of the body from the uro-genital pores to the tail. This section is elongate and laterally flattened. The variation in body shape is used by this adaptable fish. The dorso-ventral flattening of the anterior region is useful in terrestrial locomotion and benthic

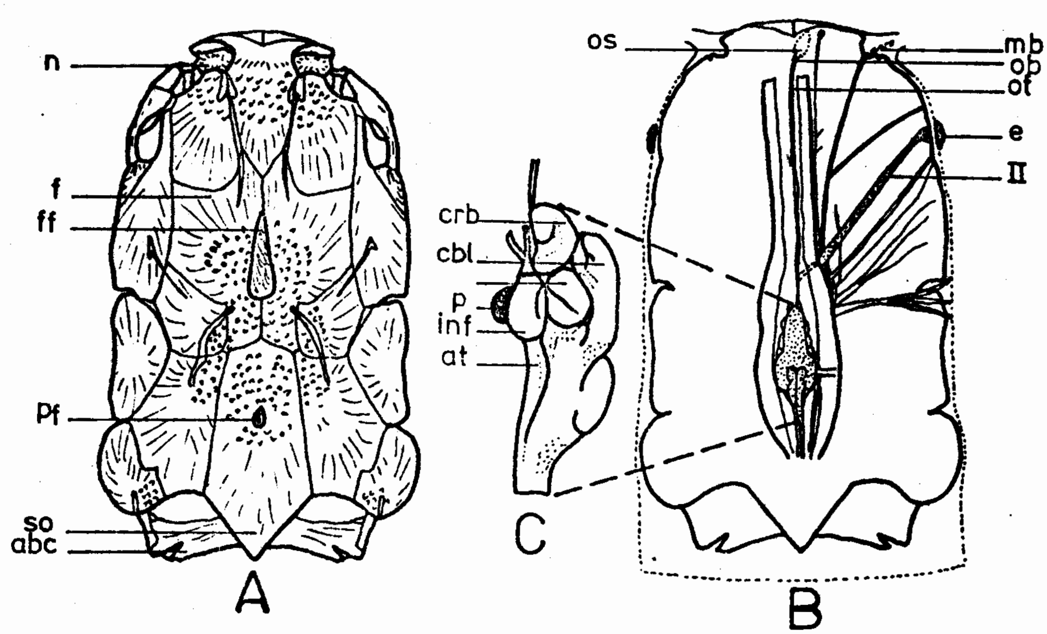

Fig. 3. Skull and brain of Clariidae. A. Skull bones, dorsal view. B. Brain cavity with major nerves, dorsal view. C. Pituitary gland and brain, lateral view. abc. - air bladder capsule; at. - accoustic tubercle; cbl. - cerebellum; crb. - cerebrum; e. - eye; f - frontal bone; ff. - frontal fontanelle; inf. - infundibulum; mb. - maxillary barbel; n. - nasal bone; ob. - olfactory bulb; os. - olfactory sac; ot. - olfactory tract; p. - pituitary gland; pf. - parietal fontanelle; so. - supra occipital bone; II - optic nerve. (Adapted from Angelopulo 1947; Lehri 1966).

feeding, while the laterally flattened tail is well adapted for swimming. Another asset of the dorso-ventral flattening of the head region is the ability to evade seine nets as mentioned previously.

The colour of *Clarias* spp. varies from a mottled beige to dark red-brown or olive green depending upon the environment. When moved from one environment to another different one, the fish's colour can change completely in only 10-15 min. Mills (1966) feels that the fish is mottled in bright light due to pigment concentrations in special cells, called chromatophores. Counter shading common to most fish is present with a dark upper surface and a white ventral surface. *C. gariepinus* of East Africa acquires a red tinge bordering its dorsal fin during the breeding season (Bailey 1966). Similar colouring was noted in spawning *C. lazera* in Israel (Clay, in press).

The entire Clariidae family is scaleless with a mucus coating over a tough skin. All of these catfishes have sensory barbels located around their large terminal mouths. There are five pairs of barbels, the largest are a continuation of the corners of the mouth and are called maxillary barbels. The inner and outer mandibular barbels are located on the lower jaw, while the nasal barbels are located on the upper jaw. All barbels are proportionately longer in the very young fish. The young fish have been observed in Lake Kariba to hang suspended by the surface tension of their long barbels; in this upright position they filter water and zooplankton through their gill rakers in order to feed (Junor, pers. comm.). The barbels have been reported to be richly supplied with taste buds (Das 1927) and are innervated by the Vth nerve (Angelopulo 1947). More recently Rajbanshi (1966) has found through histological studies that all of the barbels on *C. batrachus* are similar in makeup. Taste buds are present but no tactile organs are to be found in the epidermal region. An hypothesis for this is drawn up on the basis that *Clarias* spp. are bottom feeders while other catfishes such as *Wallago attu* which have large numbers of tactile organs are mid-water feeders.

There are two small openings located on the snout. These nasal pores are external sensing devices - the posterior opening is a slit located behind the nasal barbel while the anterior one is slightly raised. The lateral line, another external sensory receptor, extends the entire length of the trunk and caudal regions and is connected to the exterior by a series of raised pores (Mills 1966). Although not visible on the skull of a living fish, the courses of the branches of the lateral line are indicated by grooves in the bones of the skull (Angelopulo 1947).

The eyes are located on each side of the massive skull near the anterior end. They are very susceptible to damage by gillnets even though they are protected by a thick membrane (Mills 1966). Posterior to the eyes and centrally located in the skull is the frontal fontanelle and further back is the smaller parietal fontanelle. The latter is often pierced by fishermen to kill these fish.

The teeth are located in bands in the mouth and throat. The premaxillary band is in a crescent shape and was frequently used for taxonomic identification. Jubb (1967) has recently synonymized *C. gariepinus* and *C. mossambicus* as the only reason for their previous separation into two species was on the basis of their teeth patterns. Plates 1 and 2 show the upper jaws of two *C. gariepinus* from Hartbeespoort Dam in the Republic of South Africa that would have previously been separated into two species. The vomerine pads located in the throat cavity appear to serve a swallowing function. The author has observed that when these pads are stimulated with a blunt object the throat convulses in a swallowing reflex.

In *Clarias* spp. the unpaired dorsal and ventral fins are well developed and do not join the caudal fin which forms a separate rounded homocercal tail. All the fins are supported by soft dermal fin rays (lepidotrichia). As well as these soft rays each of the pectoral fins is supported by a hard calcareous spine. This serrated spine is used for both terrestrial locomotion and defence (Nawar 1954). They can inflict serious wounds which are often infected by the ever present mucus secretions of the catfishes; this has given rise to the belief that these spines are poisonous. Das (1927) reported *C. batrachus* using these spines for fighting. When overcrowded in small containers, the fish will fight until the weakest die. The author has observed that they often appear to lie side by side and by making sudden whip-like motions they endeavour to drive their spines into each other. These spines make a formidable weapon by their locking mechanism - a slight forward clockwise twist locks the spine (Nawar 1954).

The spinal column of *C. gariepinus* is made up of two sets of vertebrae totalling between 60 and 73 (Angelopulo 1947) while *C. lazera* has between 65 and 67 vertebrae (Nawar 1954). This is another indication of the close relationship of these separate species. The first five of these vertebrae are called the "complex vertebrae" (Mills 1966) and have been modified to form the Weberian ossicles which are fused to the skull and enclose a lobed air sac. This may be a special adaptation to provide better muscular attachment and flotation for the relatively large head. The first five (or less) unattached vertebrae have single thick spines. It is from these vertebrae (usually the first three) that the bones for ageing the catfish are chosen (Appelgate 1950; Balon 1974; El Bolock 1972). After these come a short series of vertebrae with double spines; the majority of vertebrae follow with single slender spines. The caudal and trunk vertebrae are similar except for the haemal canal containing the caudal vein and artery. The terminal vertebrae are connected to the haemal spines as a series of hypurals forming the base of the homocercal tail (Angelopulo 1947). There are 13 pairs of pleural ribs. These "floating ribs" are attached to the anterior surface of the ventro-lateral process of the vertebrae. From a consumer's point of view, Clariidae with their relatively small number of bones are desirable fish when compared to the Cyprinidae family which have large numbers of very fine bones throughout the body.

The sex of *Clarias* spp. can be observed externally on most fish over 17 cm in length and internally on most fish over 13 cm. Males and females can be separated on the basis of the external genitalia. The males have a sharply pointed genital papilla into which the ureter and genital ducts empty. In the female the genital opening is little more than a mole-like growth. In both sexes the uro-genital pores are located behind the anus.

The ovaries in *Clarias* spp. are paired, elongated, sac-like structures lying in the body cavity. They are usually equal in size but occasionally one is larger than the other and rarely one is absent. The caudal end of the ovary is attached to the genital papilla through a common oviduct. As maturity progresses the ovary changes colour from creamy white to greenish or reddish-brown. The testes are also paired, elongated structures but they are more flattened and ribbon-like. When immature, the testes are smooth edged but at maturity the edges become serrated. The size of the testes is generally equal but, as with the ovaries, they can vary. The colour at maturity is usually creamy white.

The pituitary gland (Fig. 3) is a white ovoid structure located immediately posterior to the prosencephalon on the floor of the brain cavity (Angelopulo 1947). It is easily removed and dehydrated in acetone and can be used for induced breeding (Van der Waal 1974).

There are two peculiarities in the African catfish: both the liver and kidney have lateral lobes embedded in the body musculature (Nawar 1955). The liver lobes are embedded behind the pectoral girdle, while the kidney lobes are located behind those of the liver (Plates 3 and 4).

The major nerves of *Clarias* spp. are large and easily traced. This factor along with the wide distribution and extreme hardiness make *Clarias* spp. an ideal fish for classroom study (Bowmaker, pers. comm.; Mills 1966). Supplying African secondary schools with indigenous fish for dissection would be a large industry in itself. This would certainly bear investigation rather than importing exotic fish into Africa and Asia where foreign exchange is always at a premium.

RESPIRATION

These catfish are one of the most widely distributed fish in Africa, often being most plentiful in environments inhospitable to other fishes. One of the greatest assets for *Clarias* spp. in regard to its adaptability is its modified respiratory system. The tropical catfish's ability to utilize atmospheric oxygen allows it to live in shallow tropical pools in which few other freshwater fish can survive due to the low dissolved oxygen levels resulting from decomposing organic matter and the high temperature regime. Most fish that are adapted to aerial respiration live in such environments (Saxena 1963). *Clarias* spp. falls into Hora's (1935) second category for air breathing fishes, i.e. those fishes from pools, marshes, and side streams.

The accessory breathing organs of *C. batrachus* are made up of the following four parts: (1) supra-branchial chamber, (2) the fans or gill plates, (3) the dendritic organ, and (4) the respiratory membrane (Munshi 1961). Recently it has been proven through electron microscopy that the respiratory organs of *C. batrachus* are modified gill structures (Hughes and Munshi 1973). The respiratory organs of the Clariidae are located in two chambers in the posterior part of the skull under the thick dermal parietal bones. Each chamber or arboescent organ consists of two dendritic tree-like growths that arise from the upper ends of the 2nd and 4th gill arches.

The respiratory chambers are walled by "gill-fans", structures that are histologically similar to gill filaments (Greenwood 1961) and which act as valves which control the retention or expulsion of air (Bowmaker, pers. comm.).

The two respiratory trees develop from the epibranchials of the gill arches. The posterior tree is always larger and more fully developed than the anterior. These arborescent organs develop late in the postlarval stage (Greenwood 1956). The first knob or tree develops about 3 cm while the anterior tree (from the second gill arch) develops somewhat later, possibly about the 5-cm stage (Greenwood 1961). This is very suitable as *Clarias* spp. take about 4-6 wk to grow to 5 cm. As the nursery habitat is still well oxygenated at this time, the fry are able to temporarily breathe through their gills.

A *Clarias* spp. releases several large bubbles through its opercular openings when rising to the surface to breathe. It then opens its mouth above the surface, closes it, and dives steeply. The angle of the dive forces the air to the back of the buccal cavity where it rises and fills the two respiratory chambers.

Donnelly (1973) suggested that the barbels are used as trigger mechanisms for stimulating the release of air; this is done by sensing the surface tension of the water as the fish rises.

Early workers thought that *Clarias* spp. would drown if kept from the surface (Boake 1866; Day 1868; Dobson 1874). It has now been proven that *C. batrachus* does not drown if prevented from reaching the surface as long as it is kept in well oxygenated water with the carbon dioxide continuously removed (Abdel Magid 1970; Hora 1935; Jordon 1976). Oxygen uptake by haemoglobin of the catfish is very good and it is remarkably insensitive to high carbon dioxide levels (Fish 1956). This latter point is very important in aerial respiration as the carbon dioxide levels would tend to build up in the intervals between aerial breathing. At oxygen levels below 1 ppm in the water all aquatic respiration stops completely as the oxygen would tend to diffuse from the blood through the gills to the outside environment (Saxena 1963).

The rate of opercular movements increases until just before surfacing, and is lowest immediately after (Abdel Magid 1970). Low oxygen tensions increase the aquatic respiration rate; at very low oxygen levels (>1 ppm) opercular movements cease. *C. batrachus* at temperatures around 30°C come to the surface as frequently as half-minute intervals; this is due to the very low dissolved oxygen (D.O.) levels at high temperatures (Das 1927).

This ability to change from aquatic respiration to aerial respiration makes the family Clariidae ideal for culture. In tropical warm water pond culture one of the greatest assets, high plankton production, is also one of the greatest drawbacks. The high phytoplankton production leads to excessive diurnal fluctuations in D.O. levels, often resulting in anoxic conditions by dawn. *Clarias* spp. are able to withstand this condition with no adverse effects. Even more difficult to use for fish culture are oxidation ponds; the high biological oxygen demand (B.O.D.) in these ponds often means that even though there is a very high level of productivity, it is almost impossible for ordinary fish to survive. Further advantage of aerial respiration for the culturist is in the marketing of live fish (Hora 1934). Because *Clarias* spp. can survive for as long as 18 h in a basket with wet grass, the marketing problems, especially in the tropics, are reduced considerably.

Several theories have been put forward for the evolution of the air-breathing fishes. Most of these are only further adaptations of an early theory put forward by Carter and Beadle (1931) and later modified by Hora (1935). This theory states that lack of oxygen in shallow tropical waters must have been responsible for evolution of the air breathing habit in these fishes. Carter (1931) also pointed out that the high carbon dioxide levels were a very important factor in this evolution. According to Hora (1935) the dendrite tree of the Clariidae was originally developed to increase the surface of the respiratory epithelium.

Although several adaptations have been added to the respiratory system of the Clariidae, several items have also degenerated. The air bladder of *Clarias* spp. is present in small fish and becomes relatively smaller as the fish grows. It is eventually enclosed in a boney capsule projecting laterally from the back of the skull, just posterior to the junction of the fused and free vertebrae (Das 1927). The genus *Xenoclarias* is one group of the Clariidae that has readapted to lacustrine conditions. The aerial respiratory organs have degenerated in these fish until they no longer surface and, in Lake Victoria, live permanently at depths of over 40 m (Gee 1969).

HABITAT AND DISTRIBUTION

Members of the Clariidae are found distributed throughout Africa from the Umtamvuma River (Crass 1966) and the Orange River in the south, to the Nile in the north; through the Near East, especially Syria, and into India and the Far East (Hora 1937). They are now also found in Hawaii and in southern Florida in the continental U.S.A. Figure 1 shows the world distribution of Clariidae.

The major habitat for *Clarias* spp. is warm shallow tropical pools, although several species have readapted to deep lacustrine conditions (viz. *Xenoclarias* spp.). In Lake Kariba the catfish was found to be more common at 2 m depth than at 5 m, and more common at 5 m than at 10 m (Mitchell, pers. comm.). The catfish is one of the most widely distributed fish in Africa. The major limiting factors to distribution are low temperatures (Pardue 1970) and salinity (Clay, in press). They have been found above and below waterfalls (Bell-Cross 1968), in pans or pools that were previously dry and have no inlet (Das 1927), and in drying river pools with only mud as a medium of support (Donnelly 1973).

Although a minimum temperature of less than 10°C is generally fatal to *C. batrachus* (Pardue 1970), a diurnal range of between 13.5 and 27.5°C (Donnelly 1973) does not seem to have any adverse effects. This tolerance of a wide diurnal range of temperatures is another strong asset for fish culture operations where the shallow ponds often can exhibit great daily fluctuations in temperature.

Salinity trials on *C. lazera* indicate that the fish cannot survive salinities over 15 ppt and, as such, estuaries of more than 50% seawater would provide an effective barrier to distribution (Clay, in press).

Their aerial respiration and ability to move over land are major adaptations allowing such wide distribution. In India, when pools are disappearing in the dry season, *C. batrachus* bury themselves in the moist mud below the surface (Das 1927). This gave "rise to the superstition [then] current amongst the peasantry that they have been rained from the clouds...as they appear in great numbers after the monsoons" begin (Das 1927). Whether these fish truly aestivate must still be proven; Donnelly (1973) observed *C. gariepinus* in drying pools in Africa and found that, even when only a thick liquid mud remains, the fish were still actively breathing. In this case predators reduced the numbers of *Clarias* spp. as the pool dried up; the major predators besides man in Africa are crocodiles (Hipple 1946), the fish eagle (Donnelly 1973; Jubb 1952; Junor 1967) and marabou storks (Donnelly 1973).

An unusual adaptation to habitat desiccation in the African catfish was observed in Natal, R.S.A. Clements (1974) observed several *Clarias* spp. in a small river pool to cross a short sand bar and jump into a "den". The den had an opening about 15 cm in diameter and contained water below ground level. This retreat to a den utilizing ground water is one method of survival when the surface water dries up. Unlike *C. batrachus* described earlier, *C. gariepinus* and its near relative the vundu *(Heterobranchus longifilis)* are only partially adapted to habitat desiccation. When conditions become too severe, these fish often try to leave the local environment, usually by means of terrestrial locomotion.

Much work has been done on movement of Clariidae over land (Boulenger 1907; Das 1927; Johnels 1957; Welman 1948). The spines are kept rigid during "walking" by a T-joint that locks into position (Nawar 1954, 1955). Johnels (1957) filmed this locomotion as a rolling movement using the spines alternately as levers to heave the body from the ground (Fig. 4 shows a sample of this motion). Sandon (1950) records *C. lazera* as moving over 200 m from a swamp to a river in the Sudan. Although terrestrial locomotion has been observed and filmed, the author has observed that it cannot successfully take place over dry ground and Bell-Cross (pers. comm.) noted that it generally involves a downhill slithering type of walk.

REPRODUCTION

The reproductive biology of a fish being considered for culture is perhaps the second most important factor after the study of feeding and growth. Many researchers have studied the reproduction of the Asian catfish (Khan 1972; Sidthimunka et al. 1966; Sidthimunka and Ekuru 1959; Wanichakorn 1962) and the African catfish (Carey and Bell-Cross 1967; Corbet 1960; Holl 1966; Nawar and Yoakim 1962; Van der Lingen 1965; Van der Waal 1974). The Asian catfish *(C. batrachus)* appears to be similar in breeding habits to the American catfish *(Ictalurus punctatus)* by breeding in dens, while the African catfish *(C. gariepinus)* more closely resembles the cultured carp *(Cyprinus carpio)* and breeds on flooded vegetation. Neither method poses any serious problems to culturists that cannot be solved by some basic research.

The African catfish was first investigated in East Africa by Greenwood (1955). He followed a spawning run in a flooded low lying area adjacent to a stream. During the time of this spawning run, he artificially fertilized some ova and found that they hatched within 23-25 h at 24°C. In later studies Greenwood (1957) found the ova hatched in nature between 36 and 42 h after fertilization. Holl (1968) found *C. gariepinus* in Central Africa had similar breeding habits and the same size ova (1.5-2.0 mm diameter) as the previously described *C. gariepinus*, and that it required 40-48 h at a temperature of 20-24°C for hatching to occur.

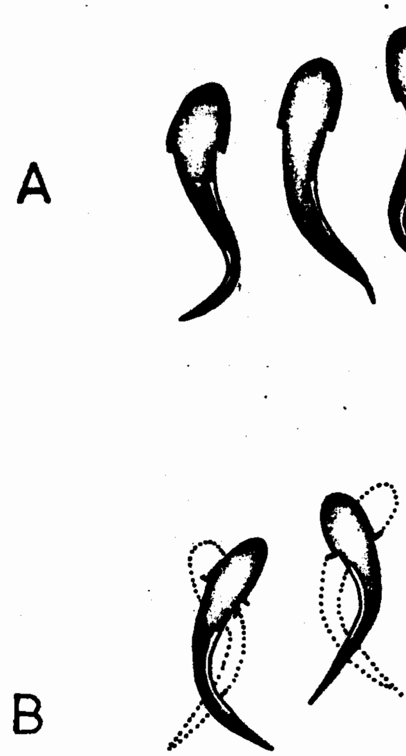

Fig. 4. The muscular contraction of the Clariidae in swimming (A) and terrestrial (B) locomotion (white shading indicates muscular contraction).

The larvae ranged in size from 3.5-4.0 mm and both Holl (1968) and Greenwood (1955) report the larvae swim actively and have a ventral sucker for resting on the substrate. Pham (1975) found the larvae of *C. lazera* when cultured must be aerated for at least the first 12 days. Bowmaker (1973), in his description of the development of a Clariid (thought to be *Heterobranchus longifilis*), records they were almost continuously quiescent, resting on the bottom. These larvae were larger than *Clarias* spp. (5.3 mm at hatching + 8 h), although the fry were approximately the same size in later development. All the above workers indicate the extreme rapidity of development in the first 50 h. This may be an adaptive feature to compensate for the short-lived nature of the flooded nursery grounds. Greenwood (1955) found the young fry could withstand diurnal temperature variations of 22-34°C. The yolk sac is completely resorbed 6-8 days after hatching when the fry begin feeding on zooplankton and insect larvae. Pham (1975) found the larvae reached 15-30 mm in 15 days in culture conditions when feeding on zooplankton.

The breeding behaviour of *C. gariepinus* was studied in aquaria by Van de Waal (1974). The spawning was found to occur at intervals, each emission of ova being made up of a small cloud of eggs followed by some gas bubbles. Van der Waal (1974) observed that "while swimming actively together, the male ... folds himself around [the female's] head and body for a period of from 15-30 sec. During the last few seconds, the male's body presses hard laterally on the female's head, shivering continuously. At this stage the female's body also starts to contract ... [and] in a sudden movement the female bends her body sideways, often pushing her face into the substrate while the male moves backwards ... still folded around the female's body and still shivering. Immediately a small cloud of ova is ejected ... ." The eggs were widely distributed over the substrate by the vigorous flicking of the female's tail. A large adhesive disc attaches the eggs to the substrate within about 60 sec. In a natural situation this adhesive nature permits wide distribution and thus adequate oxygenation of the ova. Similar behaviour was observed in the field with *C. lazera* in Israel (Clay, in press).

Unfortunately the adhesive nature of the eggs makes artificial fertilization of large numbers difficult as they tend to clump together and high mortalities result. Work needs to be carried out on artificial stripping, fertilization, and hatching of the African catfish to facilitate the production of the millions of fry required for culture. Clay (in press) has tried using the method described for carp ova (also sticky by nature) and found it successful in preventing clumping of ova.

Under natural conditions a serious problem of fry mortality among the African catfishes has been found. It is generally attributed to cannabalism, both parents and larger fry preying upon fry. This cannabalism has been a factor leading to Micha's (1975) failure to achieve survival of fry in densities over 1450 individuals per ha. After hatching, the fry of *C. batrachus* have also been found to be cannabalistic, so intensive feeding and frequent grading are required to prevent mass mortalities in culture conditions.

The ova of *C. macrocephalus* are slightly smaller in size (1.3-1.6 mm) (Sidthimunka 1972) than the ova of the African catfish although Khan (1972) found *C. batrachus* ova in India averaged 1.8 mm in diameter, with the fry hatching out at 5.8 mm. *C. batrachus* of Thailand spawn in deep water, preparing a horizontal hole or den in the bank about 20 cm in diameter and 25 cm deep. The eggs are deposited and stick to the vegetation and soil surface, and hatch in less than 20 hours at 25-37°C. *C. macrocephalus* spawn in water less than 30 cm deep (Tongsanga et al. 1963) and build their 'redd' or nest about 30 cm in diameter and 5-8 cm deep on the grassy bottom. After the eggs are deposited and stick to the substrate the male then guards the nest while the female remains close by.

Most authors indicate that, although the breeding season for both the African and Asian catfish may vary as to the month of occurrence, it nearly always coincides with the onset of the rainy season (Bowmaker 1973; Greenwood 1957; Holl 1968; Sidthimunka 1972). The author observed that *C. lazera* in Israel spawn at the end of the rainy winter season as the weather warms but before the winter flood waters recede. This latter observation may indicate that temperature is the major stimulus dependent upon sufficient water. All researchers have emphasized the short duration of their observed respective spawning runs. Bowmaker (1973) describes *C. gariepinus* from Lake Kariba as going up the rapids in "gay abandon" with no concern of damage.

Bowmaker (1973) had the unique opportunity of observing (through the clear water beneath a Salvinia mat in the Mwenda estuary of Lake Kariba) that *C. gariepinus* gathered before the floods and lay quietly on the bottom in 1-2 m of water. The suddenness and short duration of the run reported in Lake Victoria (Greenwood 1956) indicate this may also be the case there.

Seasonal maturity in summer rainfall areas follows a definite pattern as shown in Fig. 5. Until immediately before the rains few fish are truly "ripe" - yet within 12 h of a heavy rain most fish are "running ripe" (Bowmaker 1973). Both Greenwood (1957) and Holl (1968) have remarked on the "one shot" nature of the spawning run; Bowmaker (1973) found the ova diameter of *C. gariepinus* had a unimodal distribution, this being indicative of a single spawner. More recently it has been found that there is a second peak in the ova distribution at about 300 microns - too small to find by conventional

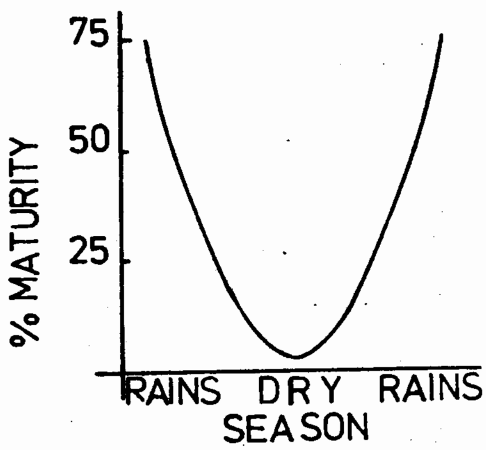

Fig. 5. Estimated percent of adult population being mature at different times of the year in tropical regions of seasonal summer rainfall.

washing and hardening techniques (Clay, in press). This latter find indicates that the 'one shot' nature of the spawning may be more attributable to environmental conditions than the reproductive biology of the tropical catfish. Idyll (1969) has remarked that *C. batrachus* spawns through much of the year in Florida. This may be because seasonal rains do not have quite the same regularity there that is found in parts of Asia and Africa.

The size at which a catfish reaches maturity seems to vary with location. Pham (1975) found cultured fish ready to breed at 8 mo of age. Table 4 gives some examples of lengths at first maturity and fecundity of ripe females. Bowmaker (1973) has called *Clarias* spp. an 'average fecund fish' and Greenwood (1955) has mentioned the high mortality in shallow flood plains for catfish fry. These two factors make it hard to understand how *Clarias* spp. can often make up over 50% by weight of the commercial catch throughout East and Central Africa. One possible explanation for this, aside from the ruggedness and large size of the Clariidae, is the possibility of multiple spawning. Pham (1975) found that artificially induced spawning could be repeated in 3 or 4 mo.

Greenwood (1957) found small fry in the lake long after the single spawning run and postulated that this meant either spawning was not confined to the streams and rivers during the floods and occurs in the lake as well, or the growth rate was low in the lake, in the order of 5 mm per month. Although the latter interpretation was favoured, this is difficult to accept in view of recent work on growth rates. Corbet (1960) has mentioned that young *C. gariepinus* (3-14 cm) were found along rocky wave-washed shores of Lake Victoria. This is in an environment with similar vigorous water movements to the temporary streams where spawning (normally) takes place. In Lake Kariba, Bowmaker (1973) found ripe fish away from the rivers at the time of breeding. From Matthes' (1960) statement that *C. gariepinus* of Lake Tanzania breed in the bordering swamps and marshes, it is not a far (evolutionary) step for the catfish to begin breeding on vegetated flooded shores of man-made reservoirs. It can thus be assumed that African catfish may in some lakes be made up of two separate breeding populations, those invading flooded streams and pans and those breeding on newly flooded shore lines or even rocky wave-washed coasts, another indication of the adaptability of this fish.

For culture purposes, leaving *Clarias* spp. to breed on their own in special breeding ponds is an expensive and often risky business, as breeding may not occur. Present-day moves for nearly all fish culture operations are towards induced breeding by chemical injection. This usually involves the injection of a pituitary extract or some substitute into an already ripe fish (see Table 5). Khan (1972) has found mashing testes and stripping ripe eggs into the sperm suspension was very successful. Problems did occur though, in that the eggs were non-floating and sticky by nature and clumping resulted. Khosa and Chandrasekhar (1972) found that a weekly intramuscular injection of 12.5 micrograms of copper acetate in ½ ml of 0.75% saline for 3 mo caused formation of many enlarged yolky eggs when compared to control fish. More experimental work will determine optimum chemical levels to stimulate such maturation and optimum hormonal levels to allow artificial stripping. This should provide the information which will result in the production of a continuous supply of fry. This is more desirable than a sudden natural production during the normal breeding season.

In male fish with the gonads surgically removed, regeneration of the testes was found to occur and a large change in the histological structure of the pituitary was noted with little or no change in the thyroid (Lehri 1966). This leaves little doubt that the pituitary is of major importance in maturation and spawning of the tropical catfish. The location of the pituitary gland is shown in Fig. 3. It is located on the ventral side of the brain attached to the infundibulum and can be found by removing the upper skull plates (supraoccipital) and exposing the brain. If tweezers are used to break the notocord, the brain can be lifted up and forward from the posterior end and the small creamy coloured ovoid body of the pituitary gland will be found beneath.

Lehri (1967, 1968) divided both the male and female sexual cycles into five phases: a) resting phase (3 mo), b) early maturing phase (4 mo), c) advanced maturing phase (2 mo), d)

Table 4. Table showing the length at earliest maturity and fecundity of the Clariidae.

Species	Location	Sex	Length at maturity (cm)	Length/Fecundity	Author
C. gariepinus	Lake Victoria, Uganda	Female		50-75/ 32-48,000	Greenwood (1957)
C. gariepinus	Lake Tanzania	Female		/ ± 4,000	Matthes (1960)
C. gariepinus	Katanga (Zaire)	Female		60-70/ 30-40,000	Coureur & Spaas (1956)
C. gariepinus	Lake Kariba, Rhodesia	Male	53		Bowmaker (1973)
		Female	44	/ 1,450/cm	
C. gariepinus	Mazoe Dam, Rhodesia	Male	43		Van der Lingen (1965)
		Female	38		
C. gariepinus	Lake McIlwaine, Rhodesia	Male	45		Munro (1965)
		Female	39	45-60/ 20-70,000	
C. gariepinus	Lake McIlwaine, Rhodesia	Male	25		Clay (in press)
		Female	28	30-70/ 4-72,000	
C. gariepinus	Oliphants River, R.S.A.	Male	40		Van der Waal (1970)
		Female	40		
C. lazera	Bangui, C.A.R.	Male	7-10 mo[a]		Micha (1975)
		Female	7-10 mo[a]		
C. lazera	Bouake, Ivory Coast	Male	8 mo[a]		Pham (1975)
		Female	8 mo[a]		
C. lazera	Lakes Edko & Mataria, Egypt	Female		35 ave/ 38,000	Nawar & Yoakim (1962)
C. senegalensis	Lake Nuguna, Ghana	Male	32		Thomas (1966)
		Female	32		
C. batrachus	[Bangeladesh]	Female		32 ave/ 11,612	Mookerjee & Mazumdar (1950)
C. macrocephalus	Thailand	Male	22		Tongsanga et al. (1963)
		Female	22		

[a]No size was given, fish were held in fish ponds.

Table 5. Dosage quantities of various chemicals and hormones to stimulate spawning in ripe Clariidae.

Species	Injection	Quantity/Dose	Reaction time (hours)	Author
C. batrachus	Pituitary extract	0.5 ml / 1 gland	8-10	Khan (1972)
C. macrocephalus	Pituitary extract	1 ml / 2.6 mg gland 1 ml / 3.9 mg gland	14-16 14-16	Tongsanga et al. (1963)
C. lazera	Desoxycorticosterone	5 mg Doca/ 100 g fish	12	Micha (pers. comm.)
C. lazera	Desoxycorticosterone	5 mg Doca		Pham (1975)
C. gariepinus	Pituitary extract	1 ml / 1 gland	15	Van der Waal (1974)

functional maturity phase (2½ mo), e) spent phase (½ mo). From this work it is possible to estimate the stage of sexual development of a population by back counting the months to the next rainy season or from the last spawning season.

The initial groundwork by fish culturists for controlled breeding has been completed. What is now needed is practical, applied work in the field of induced and controlled maturation. In effect, a systematic breeding program, with a series of local variety trials, is the only major requirement to solve many of the problems of fry porduction for catfish culture.

FEEDING AND DIGESTION

Clarias gariepinus has been described as an omnivorous scavenger by Jubb (1967). The term "omnivorous" in this case does not make it clear whether plant material makes up any significant proportion of the dietary items. The feeding habits of *Clarias* spp. have been studied in many differing habitats, giving varying results (see Table 6).

Angelopulo (1947) suggested that the short gut of *C. gariepinus* indicated a carnivorous natural history. Thomas (1966) felt that *C. senegalensis* must be carnivorous as there were no pyloric caeca in which cellulose digesting microorganisms could live. From a fish culture point of view, the most important query is not whether *Clarias* spp. can digest cellulose but whether they can use plant proteins. Poll (1964) found *Clarias* sp. do ingest plant material, and Cockson and Bourne (1972) listed plant material in the diets of Lake Chilwa *C. gariepinus*. Munro (1965) found that in certain locations *C. gariepinus* in Lake McIlwaine feed on large amounts of plant material. Many authors accept at the outset of their study that *Clarias* spp. are indiscriminant feeders and the presence of large quantities of non-animal material, which is of little food value to a carnivorous species, must be regarded as incidental (Groenwald 1964). It is on this basic point (the ability of *Clarias* spp. to utilize plant material) that the entire potential for future culture of the Clariidae rests.

In Thailand, due to high popular demand and large quantities of relatively cheap low quality marine trash fish, *Clarias* spp. culture has become an inportant industry in the last 20 yr. Even in this case, it will be necessary to utilize other fish feeds when technology finds alternative uses for this previously cheap animal protein feed. In Bangladesh it was found that over a 6-mo period *C. batrachus* lost weight when fed a total plant diet (Mookerjee and Mazumdar 1950). Preliminary experiments on plant diets have been carried out in Egyptian fish ponds (Iman et al. 1970). Unfortunately confusion over wet weight-dry weight conversions makes the data inconclusive, but this work does indicate *C. lazera* can survive and grow on a diet composed of plant materials and whatever natural food is available in the ponds.

Generally speaking, surveys show a change in diet with size of fish. A suitable diet must maintain the health of the fish, allow flesh production, and in a fish culture situation allow a profit with or without supplemental feeding. Fish culturists in developing countries are interested in fish about 25 cm (250 g) or less in size. For the initial growth of this size catfish, the most important natural foods are insects and zooplankton; a vegetable substitute needs to be found to allow supplemental feeding.

Yanni (1972) found that adding olive oil (an unsaturated fat) to the diet of *C. lazera* increased the fat and reduced the water balance in almost all tissues; when added to the diet in excess, the fat tends to be laid down as unsaturated fat in the fat bodies. This information is useful, as it indicates *Clarias* spp. can utilize small amounts of fat as a concentrated energy source in supplemental feeding for pond culture. This would result in less protein

Table 6. Feeding habits of the African catfish *(Clarias gariepinus)* from various locations.

Survey location	Season	Fish length (cm)	Food types (% volume) (%* frequency) plankton	fish	insects	molluscs	non-animal	Author
Barberspan, TVL., RSA			++	++	+		+	Groenewald (1964)
Barberspan, TVL., RSA		0-12	11%					Schoonbee (1969)
		40+	22%					
Vaal River, TVL., RSA			+	+	++		+	Groenewald (1964)
Oukskei River, TVL., RSA			++		+		++	
Incomati River, TVL., RSA	Summer	35	1%	69%	6%	8%	13%	Gaigher (1969)
	Winter	35		17%	24%	27%	9%	
Lake Sibayi, Natal, RSA			15%	30%	12%	5%	7%	Minshull (1969)
Wankie National Park, Rhodesia					+++			Weir (1972)
Savory Dam, Rhodesia	Summer	3	++					Holl (1968)
		3-8			++			
Ngondoma Dam, Rhodesia			30%*	12%*	25%*	4%*	12%*	Toots (1969a)
Nyambuia Dam, Rhodesia					35%*	4%*	55%*	Toots (1969b)
Cleveland Dam, Rhodesia				11%*	30%*		24%*	Toots (1968)
Lake McIlwaine, Rhodesia		1.2-7.6	+	+	++			Munro (1967)
		20-40	4%	3%	85%	8%	+	Munro (1965)
		40-60	21%	2%	55%	18%	+	
		60+	65%	1%	14%	9%	10%	
		5-30		++				Murray (1975)
		30+	++	+				
	Summer			35%*	35%*	15%*		Clay (in press)
	Winter		22%*	34%*	43%*	13%*	40%*	
Lake Kyle, Rhodesia	Summer	20+		15%*	29%*	26%*		
	Winter	20+	19%*	36%*	31%*	27%*	4%*	
Mazoe Dam, Rhodesia	Summer			10%*	50%*			
	Winter				39%*		13%*	
Savory Dam, Rhodesia	Summer	0-20			100%*			
		20-50	6%*	4%*	50%*		14%*	
		50+	10%*	10%*	40%*	12%*	14%*	
	Winter	0-20	50%*	16%*	32%*	8%*		
		20-50	51%*	17%*	35%*		13%*	
		50+	43%*	15%*	7%*	7%*	7%*	
Lake Kariba, Rhodesia/Zambia			++					Bowmaker (1973)
Kafue Flood Plan, Zambia				++	++			Carey (1971)

Table 6. (cont'd)

Survey location	Season	Fish length (cm)	Food types (% volume) (%* frequency) plankton	fish	insects	molluscs	non-animal	Author
Lake Chilwa, Malawi			+	+			+	Cockson & Bourne (1972)
Lake Malawi, Malawi				++				Fryer & Iles (1955)
Lake Ruka, Tanzania			+	+	++	+	+++	Mann (1964)
Lake Victoria, Uganda					90%			Corbet (1957)
Lake Victoria, Uganda		1-1.2	+		+			Greenwood (1957)
		24-90	2%	75%	23%	1%		Corbet (1961)
			+	++	+	+		Graham (1929)
Bugungu Stream, Uganda		0-15	9%	45%	44%			Corbet (1961)
Victoria Nile, Uganda		10-20	++		++			
Lake Nuguna, Ghana			5%	2%	75%		7%	Thomas (1966)

Note: + indicates the relative importance of feeding when the data is not compatible with the table.

being broken down for metabolic energy and more being available for tissue growth. This should lower the total protein input required for catfish production.

The rate of gastric digestion is loosely related to the time and size of the meal (Palmer 1973). The calorific value of a meal of fresh fish was found to change from 4.8 Kcal g^{-1} dry weight at ingestion to 4.1 Kcal g^{-1} at defaecation (Palmer 1973). This indicates that the fat of the eaten fish is being utilized in preference to the carbohydrates and/or proteins (these have a base calorific value of about 4.4 Kcal g^{-1} dry weight). As it can be assumed that fish protein will be highly digestible for *Clarias* spp., it follows that *C. gariepinus* must utilize fats relatively efficiently while not as readily digesting carbohydrates.

During starvation fish tend to utilize their carbohydrate stores (glycogen) first and afterwards draw on their fat (lipid) reserves (Love 1970). Kiermeir (1939) showed that, in starvation, fish which were sluggish tended to maintain very constant blood glucose levels, while active fish showed a gradual decrease. Yanni (1964) and Al-Gauhari (1958) found that little or no change in blood glucose levels occurred in *C. lazera* after 5-7 mo starvation. Thus it can be assumed that *Clarias* spp. fit into the category of sluggish fish (Love 1970), which might indicate a greater amount of their food energy will go into flesh production and less into activity.

The pH of the stomach of *C. gariepinus* is just slightly alkaline (pH 7-8) when empty, but becomes acidic (pH 3-4.5) when food is ingested. The intestine is generally slightly acidic (pH 5-6) (Palmer 1973). Cockson and Bourne (1972) found protease in the stomach and anterior intestine of *C. gariepinus* with an optimum enzyme activity level occurring at a pH of 4-6. The enzyme activity was found to be four times as great in the stomach as in the intestine. Most of the protease was found to be pepsin with a little trypsin; these enzymes are very general in nature and indicate a strong likelihood of digestion of all proteins with no specialization for the digestion of either plant or animal protein. Pepsin is found in both herbivorous and carnivorous mammals where it acts through the hydrolysis of proteins, especially among the amino acids, phenylalanine, tryptophan, tryosine, and leucine (White et al. 1968).

Cockson and Bourne (1972) also found amylase produced and located in the anterior and posterior intestine of *C. gariepinus*. Amylase has an optimum activity at a pH between 4.5 and 7 (White et al. 1968). As this shows that starch digestion cannot begin until the food is in the intestine, *Clarias* spp. would appear to be inefficient at starch (carbohydrate) digestion.

Palmer (1973) found that the percent inorganic material in the food increased from ingestion to defaecation with the greatest change occurring between the intestine and the rectum. This indicates that absorption is mainly of organic matter and occurs largely in the intestine as would be expected.

Clarias spp. has few predators. Crocodiles (Cott 1954; Hipple 1946) and predatory birds (Donnelly 1973; Junor 1967) are the only significant natural predators besides man. This may be the reason why cannibalism is often a problem in dense *Clarias* spp. populations. Cloudsley-Thompson (1959) put forward a theory that cannibalism is often a means of keeping population density down and conserving protein within a species.

Many surveys have indicated the importance of filter feeding habits of *Clarias* spp. (Table 6). Although juvenile catfish (<3 cm) were known to feed on zooplankton, it was often thought that adult fish (>30 cm) were more ontogenetically adapted to filter feeding than young juvenile fish (between 3 and 30 cm). This was because it was thought that the number and length of the gill rakers increased and the spacing decreased with length (Alexander 1966; Gilchrist and Thompson 1913; Jubb 1967; Thomas 1966). Murray (1975) found that the gill raker spacing in fact increases with length in *C. gariepinus*. Although the young *C. gariepinus* (3-30 cm) did not filter feed in Lake McIlwaine, under laboratory conditions they did successfully filter feed on plankton. This physical adaptation of *Clarias* spp. under 30 cm to filter feed is important when deciding on species selection for warm water pond culture, especially where temperatures warrant fertilization of the water.

Food selection in nature is variable; the Clariidae family tend to be opportunistic feeders. In Lake Victoria, Corbet (1956) found *C. gariepinus* so unspecialized in feeding that, when *Simulium* spp. which made up 90% of the diet were removed by insecticides (DDT), the fish changed to a diet of plants, molluscs, etc. Weir (1972) found *C. gariepinus* in pools in Wankie National Park, Rhodesia, feeding exclusively on the only food available, insects. Munro (1965) found that during the lunar emergence of chironomids *C. gariepinus* fed exclusively on these insects. Similar exclusive feeding patterns were noted by the author at Lake Kyle, Rhodesia, with termite flights after the heavy rains, and in Sand River Lake, Swaziland, during the seasonal bivalve (Lammellibranchia) "spawning run" into shallow water. Groenwald (1964) found *C. gariepinus* diet to be greatly dependent on food availability in different environments; thus the catfish becomes a piscivore when there is an abundance of fish available. In Zambia, Carey (1967) and Tait (1967) found *Clarias* sp. to be a major factor in fish predation, especially in the Kafue River system, in the absence of the tiger fish (*Hyrocynus vittatus*). Generally, it can be stated that juvenile Clariidae have been found to be filter feeders at less than 3 cm in length (Corbet 1961; Munro 1967). Thereafter they tend to feed on almost anything, with a preference for animal protein.

Even when food may be in short supply *Clarias* spp. have one alternative adaptive feature. Social or pack hunting was observed and recorded by several authors (Anon. 1975; Donnelly 1966; Pooley 1972). During this activity, *C. gariepinus* of 75 cm and over form a long crescent-shaped line and drive small fish ahead of them by making a violent commotion within the water. They drive the prey fish along the shore until they reach a small bay or inlet which they can effectively seal off. They then commence to feed.

Thomas (1966) stated that the head and body adaptations of *C. senegalensis* indicated a sluggish bottom dweller; in Lake Nungua, Ghana, the catfish he observed were predominantly benthic feeders. Groenwald (1964) states that several features of the head region of *C. gariepinus*, such as size of mouth and bands of small (cardiform) teeth, are adaptations for manipulating large prey; the catfish he observed were largely piscivorous. Gilchrist and Thompson (1913) state that, for this latter species, the large number of fine, closely set gill rakers is clearly an anatomical feature of a plankton feeder. With such variable adaptations and catholic feeding habits, it is unlikely that food would ever provide a serious environmental barrier to the dispersal (Corbet 1961) or growth of these fish.

GROWTH AND PRODUCTION

The growth of the Clariidae has been the subject of much speculation but little detailed study. Due to their wide range of feeding habits, they have been repeatedly mentioned as having a great potential for culture (Brown 1955; Couveur and Spaas 1956; Symes 1954). This potential can only be realized if their growth rate is rapid and efficient under culture conditions. Little work has been done in this field and what has been done is very contradictory (see Table 7). The basic study (of production) that is so important for the utilization of this family of fishes for aquaculture has been sadly neglected.

The two very high growth rates of *C. gariepinus* found by Munro (1965) and Van der Waal (1973), shown in Table 7, appear to be rather overly optimistic. Munro (1965) utilized monthly frequency peaks in commercial gillnets to predict the growth of modal groups. With fish caught by gilling (the more regular way of a gillnet working) this is difficult (Holt 1963) and since *Clarias* spp. have a tendency to tangle their spines in gillnets of nearly any size, it is virtually impossible to accurately use this method. It is also possible that he "lost" the first year or two as the catfish would be too small to be adequately sampled by the commercial fisheries smallest nets (50 mm stretched mesh). Van der Waal (1974) used spines to age his fish. The initial growth rate he found for the first year is extremely high, especially when considering the growth rate in second and subsequent years. There is a possibility that, as was pointed out by Marzolf (1955), the lumen of the spine of the catfishes enlarges with age, thus reabsorbing the surrounding bone and with it the first ring. Corbet (1960) observed *C. gariepinus* in Lake Victoria to be between 6 and 12 mo old at 11 cm. This tallies well with the observations by Greenwood (1955) and Holl (1968) for wild fish (see Fig. 6).

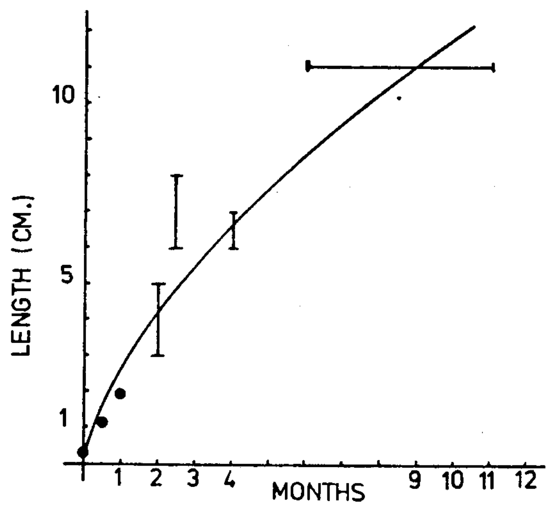

Fig. 6. Growth of juvenile *Clarias gariepinus* in east and central Africa (from data of Corbet 1960; Greenwood 1957; Holl 1968).

Catfish under conditions of culture have a much more rapid growth rate. Sidthimunka (1972) found cultured *C. macrocephalus* in Thailand had reached a marketable size of 250 g (approximately 30.0 cm) in 4-5 mo, an average of about 55 g month^{-1}. Van der Waal (1970) achieved similar growth rates for *C. gariepinus* in the Republic of South Africa. By using pelleted feed, the fish reached 300 g in a 5-mo growing season (60 g month^{-1}). Mortimer (1964) reared *C. gariepinus* in fish ponds in Zambia and in a 6-mo growing season the fish grew from 675 to 1666 g, an increase of over 160 g month^{-1}. During the colder months, Mortimer grew fish from 50 to 300 g in 5 mo (50 g month^{-1}).

Table 7. Sample field growth rates of the Clariidae in the tropics.

Species	Ageing technique[a]	Location	Sex	Total length (cm) at end of time (Days) 0	7	15	60	120	270	(Years) I	II	III	IV	Author
C. batrachus	Obs.	(Bangeladesh)		.58	1.0									Mookerjee and Mazumdar (1950)
C. lazera	Vert.	Egypt	M							19.1	29.5	38.1	46.7	El Bolock (1972)
			F							19.3	29.8	37.2	44.8	
C. lazera	Obs.	C.A.R.				3[b]								Pham (1975)
C. gariepinus	Obs.	Uganda		.4	.8									Greenwood (1955)
C. gariepinus	Vert.	Zambia								10.0[c]	15.0[c]	20.7[c]	29.0[c]	Pivnicka (1974)
C. gariepinus	Obs.	Rhodesia							13					Bowmaker (1973)
C. gariepinus	Obs.	Rhodesia					4.3	6.2						Holl (1968)
C. gariepinus	CCC	Rhodesia	M							30.0	47.0	60.0	72.0	Munro (1965)
			F							27.0	37.0	50.0	58.0	
C. gariepinus	Spine	R.S.A.								40.0	44.0	50.0	60.0	Van der Waal (1973)

[a]Abreviations are: Obs. - Observation
Vert. - Vertebrae ageing
Spine - Spine sections
CCC - Commercial gillnet catch curves

[b]Average of range of 2.5-3.5 cm given by author

[c]Length corrected to total length as original paper had them expressed as standard lengths

Feeding *Clarias* spp. in culture is another aspect requiring a great deal of future work. Little has been done on this subject even though *Clarias* spp. are widely cultured in some countries. Micha (pers. comm.) reported obtaining yields of 16-18 tons ha^{-1} in the Central African Republic (CAR) feeding *C. lazera* on cottonseed cake and brewers' waste. Van der Waal (1970) in the Republic of South Africa (RSA) found production in ponds with no feeding to be less than 70 kg ha^{-1}, with a mortality rate of 93%. In fish ponds with supplemental feeding of pelleted food, production was found to be 3.2 tons ha^{-1}, with a 90% mortality. The conversion rate of these latter fish was found to be between 5:1 and 6:1 (dry pellets:live weight fish). This does not compare very favourably with the 6:1 conversion ratio (wet weight food:live weight fish) by Sidthimunka (1972) in Thailand with catfish fed on marine trash fish.

Khan (1972) noted that cannibalism occurs among the fry if there is much size variation. The problem of cannibalism, a probable reason for Van der Waal's (1970) very high mortalities, is very common with *Clarias* spp. of southern Africa. It is another topic that requires much work to determine its true significance to culture.

The culture of *Clarias* spp. both alone and in polyculture with *Tilapia* spp. (Symes 1954) and other species requires "variety trials" in many locations before it can be offered to farmers and/or companies as a feasible proposition. This type of work is generally very time consuming, although not necessarily expensive. Until this is done, the many well-documented exotic species will continue to lure potential culturists away from indigenous species. Although some of the needed trials have begun in francophone Africa, it is imperative that the necessary trials should begin throughout Africa and Asia as soon as possible to allow the fullest utilization of indigenous fish for culture.

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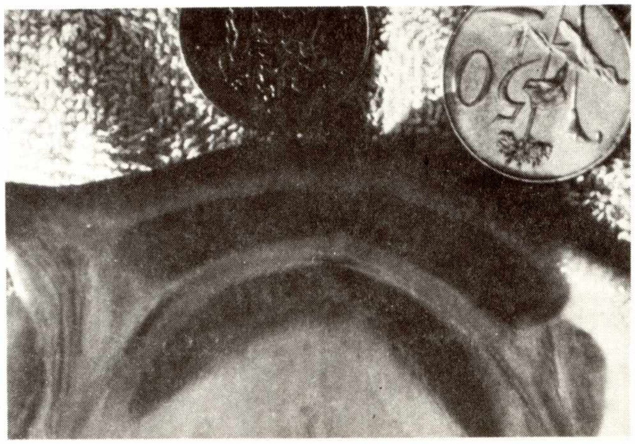

Plate 1. Dentition of upper jaw of *Clarias gariepinus* that would previously have been named *Clarias mossambicus* (from the Hartbeespoort Dam, Republic of South Africa).

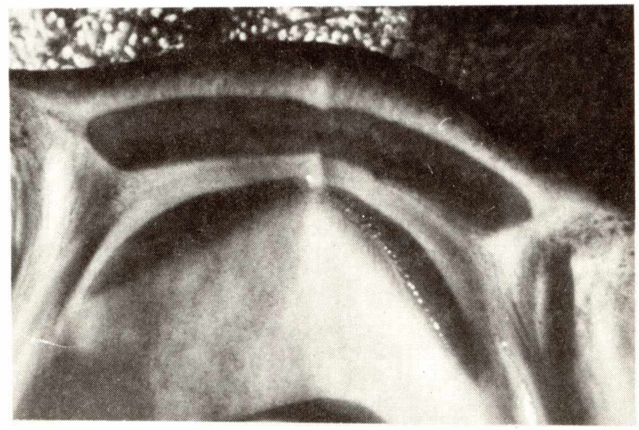

Plate 2. Dentition of upper jaw of typical *Clarias gariepinus* (from Hartbeespoort Dam, Republic of South Africa).

Plate 3. Liver of dissected *Clarias gariepinus* showing (arrow) hepatic blood vessel leaving main body of liver to link to the lateral liver lobe. Note orange coloured flesh - the flesh of the African catfish has a venison type texture (from Sand-River Lake, Swaziland).

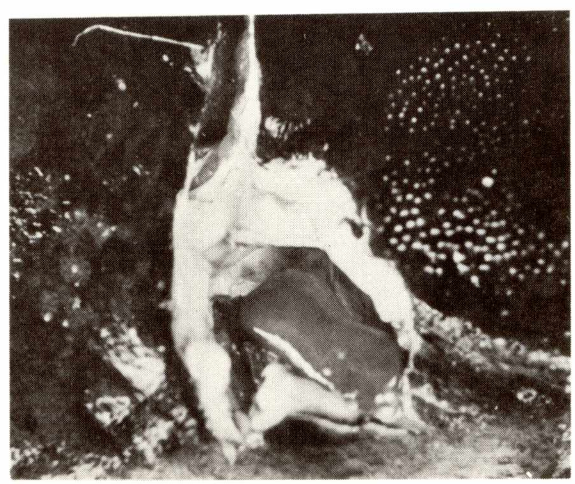

Plate 4. Lateral liver lobe exposed externally on *Clarias gariepinus*. Entry made laterally immediately posterior to skull: note tubercles on skull plates (from Sand-River Lake, Swaziland).